# NanoVNA

Jim Gragg, W5LXC

- What is it?
- Where can you get it?
- What can you do with it?
- Supporting PC Software (NanoSaver)
- Practical examples

NOTE: This is not a full tutorial. It's intended to demonstrate many of the capabilities of the NanoVNA

### Disclaimer

I'm not an experienced Ham operator and my background is digital electronics. I understand "1's" and "0's. I love experimenting but have lesser understanding of HF analog circuits. They are "magic" to me, so please bear with me as I go through this presentation. Any comments are welcome and encouraged.

### What is the NanoVNA?



Instrument used to analyze the behavior of various analog systems over a range of frequencies (more on this later)

- Sweep Range: 50kHz to 1500 mHz
  - Uses the si5351 clock generator to provide direct output in the 50KHz-300MHz frequency range
  - The 3<sup>rd</sup> harmonic is used for the 300MHz-900MHz band
  - The 5<sup>th</sup> harmonic is used 900MHz-1.5GHz band
- Display: 2.8" TFT (320x240) or 4" TFT (320x480) Touch Screen
- 101 measurement points (screen resolution)
- Interface: USB > USB type C
- RF output: -13dBm (50nW)
- Accuracy: <0.5ppm
- Scanning Points: 101 (fixed)
- Display Tracking: 4
- Display Marking 4
- Setting Save 5

### Where can you get the NanoVNA?

a [Upgraded] AURSINC NanoVNA- x +	~ - O X
← → C (a amazon.com/AURSINC-NanoVNA-H-Vector-Network-Analyzer/dp/B07Z5VY7B6/ref=d_bmx_dp_3al76mzn_sccl_2_3/139-0402255-5905162?pd_rd_w=PpCCp&content-id=amzn (	G 🖻 🖈 🗉 🖬 🚺 🗐 🗄
🔹 Keep Your Bass Boa 🔹 Keep Your Bass Boa 🍇 Lords Supper Table 🧚 Wrangler - The Wra 🚺 55+ Easy Keto Dinn 💋 1992 Mariner Outb 🔡 1/4 Wave Ground P 🧱 Coax Calculator 🗼 West	t Mountain Rad 🗈 Precedent Bucket H »
Industrial & Scientific ~     Search Amazon	p, sign in Returns Cart
🚍 All Back to School Off to College Clinic Best Sellers Customer Service Amazon Basics Music Prime - Today's Deals New Releases Books Registry Fashion Amazon	n Home Shop Black Business Month
Industrial & Scientific Janitorial & Facilities Safety Supplies Medical Supplies Food Service Diagnostic Equipment Material Handling Educational Supplies Sealants and Lubricants Additive Manufa	acturing Laboratory Supplies
Industrial & Scientific > Test, Measure & Inspect > Electrical Testing > Spectrum Analyzers	
[Upgraded] AURSINC NanoVNA-H Vector Network Analyzer 10KHz -1.5GHz Latest HW Version 3.6   HF VHF UHF Antenna Analyzer Measuring S Parameters, Voltage Standing Wave Ratio, Phase, Delay, Smith Chart Visit the AURSINC Store	Enjoy fast, FREE delivery, exclusive deals and award- winning movies & TV shows with Prime Try Prime and start saving today

	Analyzer Medsuring's Parameters, voltage standing wave Ratio, Phase, Delay, Smith Chart Visit the AURSINC Store 4.6 **** 1,029 ratings   53 answered questions Amazon's Choice in Spectrum Analyzers by AURSINC	winning movies & TV shows with Prime Try Prime and start saving today with Fast, FREE Delivery
	Source Starter Savings: Save 5% on AURSINC 10kHz-1.5GHz NanoVNA Vector Network A 2 Applicable Promotion(s) *	
	Color: Black	Or fastest delivery <b>Tomorrow</b> , <b>August 4</b> . Order within 3 hrs 29 mins © Delivering to Athens 75751 - Update location
	Brand AURSINC Color Black	In Stock
Roll over image to zoom in	About this item	Qty: 1 V Add to Cart

2.3" version of the newer Hugen design instead of original edy555 design

### Where can you get the NanoVNA?



4" version of the newer Hugen design instead of original edy555 design

### What can you do with the NanoVNA?

- Measure the performance of an antenna system (bandwidth, SWR, impedance, Return Loss more)
- Measure the length of a piece of coax (Got any bundles of coax laying around?)
- Find fault point in coax
- Measure inductance or capacitance (Who doesn't have a junk box of assorted coils and capacitors?)
- Measure performance of a low pass filter, notch filter, balun, unun, etc
- Measure insertion loss of a circuit

### NanoVNA Menu Structure Map

![](_page_6_Figure_1.jpeg)

### NanoVNA-saver software

Free Download from: <u>https://github.com/NanoVNA-Saver/nanovna-saver/releases/tag/v0.6.2</u> Download the PC file: <u>NanoVNASaver.win.x64.zip</u>

#### **Current features**

- •Operate and read data from a NanoVNA, uses only raw data from NanoVNA and does calculations
- Splitting a frequency range into multiple segments to increase resolution (tried up to >10k points)
- •Averaging data for better results particularly at higher frequencies
- •Displaying data on multiple chart types, (Smith, LogMag, Phase and VSWR-charts, for S11 and S21)
- •Displaying markers for impedance, VSWR, Q, equivalent capacitance/inductance etc. at locations
- •Displaying customizable frequency bands as reference, for example amateur radio bands
- •Exporting and importing 1-port and 2-port Touchstone files
- •TDR function (measurement of cable length) including impedance display
- •Filter analysis functions for low-pass, high-pass, band-pass and band-stop filters
- •Display of both an active and a reference trace
- •Live updates of data from the NanoVNA, including for multi-segment sweeps
- •In-application calibration, including compensation for non-ideal calibration standards
- •Customizable display options, including "dark mode"
- •Exporting images of plotted values

### Sample of my Random Wire Antenna NanoVNA-Saver display

![](_page_8_Figure_1.jpeg)

# Important: Before measurements, you need to calibrate for the setup you're using to get the most accurate results

Calibration involves the following steps from the NanoVNA menu:

- 1. Set the sweep range you plan to operate over
- 2. Measure 3 points on CH0 using the standards that come with the NanoVNA (Open, Short, 50 Ohm load)
- 3. Measure the isolation on CH1 using the 50 Ohm load
- 4. Measure the through measurement between CH0 and CH1
- 5. Save the results
- 6. Note NanoVNA-Saver has its own calibration function but performs it similarly.

### Warning: Antenna static can damage NanoVNA

For the first test, let's measure some coax length.

My cable length extension is 10 feet or 3 meters and it appears to be RG174 cable which has a published velocity factor of 66%. We can use the NanoVNA to measure TDR and get a pretty accurate cable measurement.

NanoVNA-Saver gave a length of 2.966m

The NanoVNA itself has two ways to measure:

- There is a cable measurement function accessed from the Menu – MEASURE>CABLE giving a measurement of 2.937m
- I saved a setup from YouTube in RECALL1 and it measured 2.937m

![](_page_10_Figure_6.jpeg)

Why is there a difference in measurement? From what I understand, each uses a different measurement approach. Which is better? All are within 2% of the actual.

### Measuring various aspects of a VHF Dipole Antenna System

- 1. Use CHO (S11) Port to scan VHF Band (144 to 148 MHz)
- 2. Remember to calibrate, especially at higher frequencies that are more sensitive to setup
- 3. Adjust Dipole length to about ½ wavelength, 50 cm each side
- 4. Examine SWR, impedance and return loss
- 5. Use NanoVNA-Saver to get a better view of the sweep
- 6. How does this antenna perform on 70 cm (420-450 MHz)?

### 2m band sweep of the 1/2wave 2m dipole antenna system

![](_page_12_Figure_1.jpeg)

### 70cm band sweep of the 1/2wave 2m dipole antenna system

![](_page_13_Figure_1.jpeg)

### How to measure the value of an inductor or capacitor

- 1. Use CHO (S11) to scan a frequency range
- 2. What happens to inductors and capacitors as you increase frequency?
- 3. Use a lower frequency range to determine the value
- 4. I'll use a sweep of 10 KHz to 1 MHz. You can adjust the sweep range as needed for your component.
- 5. Another question. Where on the Smith Chart is the highest inductance, highest capacitance?
- 6. Let's measure an inductor and a capacitor with the NanoVNA and NanoVNA-Saver...

### Measured value of a 180 uH inductor

![](_page_15_Figure_1.jpeg)

### Measured value of a 1000 pF capacitor

NanoVNA Saver 0.6.2.post1.dev2+g2f8c534 (Sweep: nanovna\_2023-08-10 17:03:20 @ 101 points)

ð

X

Start 10kHz Center 5.005MHz Frequency: 10.0000 kHz VSWR: 289.538 25 0 Impedance: 9.89k-j6.74k Ω Return loss: -0.060 dB Stop 10MHz Span 9.99MHz Series L: -107.2 mH Quality factor: 0.681 Series C: 2,3629 nE \$11 Phase: \_0.27° Segments 1 99.90kHz/step Parallel R: 14.477 kO S21 Gain: -51.812 dB -2 Parallel X: 748.8 pF S21 Phase: 133.05° 19.0 Sweep settings ... 100% -4 Frequency: 3.00700 MHz VSWR: 101.647 Sweep Impedance: 1.01-j51.5 Ω Return loss: -0.171 dB 13.0 Series I: -2.7268 uH Quality factor: 50.8 Markers Series C: 1.0274 nF S11 Phase: -88.27° -6 Parallel R: 2.6179 kΩ S21 Gain: -69.656 dB Marker 1 10kHz 📕 🔘 Parallel X: 1.027 nF S21 Phase: 57.27° 3.007MHz 🚺 🔘 Marker 2 7.0 Marker 3 -8 Marker 3 10kHz 🚺 🔘 Frequency: 10.0000 kHz VSWR: 289.538 10kHz Marker 4 0 -0.060 dB Impedance: 9.89k-j6.74k Q Return loss: SWR: Series L: -107.2 mH Quality factor: 0.681 10kHz 📘 🔿 -10 Marker 5 1.0 S11 Phase: Series C: 2,3629 nF -0.27° 10.00M 10.00k 5.005M 10.00k 5.005M 10.00M Enable Delta Marker Reference Parallel R: 14.477 kΩ S21 Gain: -51.812 dB Parallel X: 748.8 pF S21 Phase: 133.05° S11 Smith Chart \$11 IZI Locked O Hide data 11.87 TDR Frequency: 10.0000 kHz VSWR: 289.538 Impedance: 9.89k-j6.74k Q Return loss: -0.060 dB Estimated cable length: 3.687m 9.541 Series L: -107.2 mH Quality factor: 0.681 Time Domain Reflectometry ... Series C: 2.3629 nF S11 Phase: -0.27° Parallel R: 14.477 kQ S21 Gain: -51.812 dB Parallel X: 748.8 pF S21 Phase: 133.05° Reference sweep 7.216 Set current as reference > Reset reference S11 4.852 Min VSWR: 91.340 @ 9.90010MHz Serial port control Return loss: -0.190 dB Port COM4 (H) Rescan 2.527 S21 Disconnect Manage Min gain: -101.733 dB @ 3.30670MHz Max gain: -51,812 dB @ 10,0000kHz Files ... Calibration ... 202.5 4.915M 9.801M 29.89k Analysis Dicolay catu 5:04 PM 2 W E 0 🔮 101°F Sunny \land 🗓 📴 🚛 🕼 H 昂 8/10/2023

### Measuring Performance of Low Pass Filters

- 1. We need to use CH0 (S11) for output to the filter and CH1 (S21) for input from the filter
- 2. We can sweep the desired frequency rangy range, i.e. various ham bands
- 3. Set Markers at the fundamental frequency desired and 2<sup>nd</sup> harmonic, and 3<sup>rd</sup> harmonic
- 4. Question: What is FCC requirement for attenuation of 2<sup>nd</sup> harmonic of a frequency below fundamental emission?
- 5. Let's look at the performance of a 40m, 7 element Chebyshev Filter
- 6. After that, we'll look at a multiband, relay switched, 5 element Chebyshev Filter

#### §97.307 Emission standards.

(d) For transmitters installed after January 1, 2003, the mean power of any spurious emission from a station transmitter or external RF power amplifier transmitting on a frequency below 30 MHz must be at least 43 dB below the mean power of the fundamental emission. For transmitters installed on or before January 1, 2003, the mean power of any spurious emission from a station transmitter or external RF power amplifier transmitting on a frequency below 30 MHz must not exceed 50 mW and must be at least 40 dB below the mean power of the fundamental emission. For a transmitter of mean power less than 5 W installed on or before January 1, 2003, the attenuation must be at least 30 dB. A transmitter built before April 15, 1977, or first marketed before January 1, 1978, is exempt from this requirement.

### Measurement of 40m, 7-element Chebyshev low pass filter

![](_page_19_Figure_1.jpeg)

### Measurement of 40m, 5-element Chebyshev low pass filter

![](_page_20_Figure_1.jpeg)

### YouTube Videos of if interest

How to measure coax length: https://www.youtube.com/watch?v=9thbTC8-JtA

How to evaluate an antenna system: https://www.youtube.com/watch?v=xa6dqx9udcg

How to measure the value of inductors, capacitors: <a href="https://www.youtube.com/watch?v=Pti8Erw\_Kkg">https://www.youtube.com/watch?v=Pti8Erw\_Kkg</a>

How to measure the performance of a low pass filter: <a href="https://www.youtube.com/watch?v=F17mN5uuzGY">https://www.youtube.com/watch?v=F17mN5uuzGY</a>

Velocity factor calculation: https://www.youtube.com/watch?v=aWvPB299U60

### **BACKUP SLIDES**

### Random Wire Antenna scan with Ferrite (TF140-43) 9:1 UnUn

![](_page_23_Figure_1.jpeg)

### Random Wire Antenna scan with Powder Core (T200-2) 9:1 UnUn

![](_page_24_Figure_1.jpeg)

### UnUn scan of Ferrite (TF140-43) 9:1 UnUn with 440 Ohm Load

weep control	Marker 1	^	C11 VEWD	S11 Debum Loss (dD)	
art 3.0MHz Center 16.5MHz op 30MHz Span 27MHz	Frequency: 3.81000 MHz Impedance: 46.4+j1.29 Ω Series L: 53.988 nH	VSWR: 1.082 Return loss: -28.059 dB Quality factor: 0.028	3		
egments 1 270.0kHz/step	Series C: -32.322 nF Parallel R: 46.449 Ω Parallel X: 69.681 μH	S11 Phase: 159.42" S21 Gain: -70.934 dB S21 Phase: 98.28°	2.5	-14	
100%	- Marker 2			-16	
Sweep Stop	Frequency: 7.32000 MHz Impedance: 45.9+j629m Ω	VSWR: 1.090 Return loss: -27.327 dB	20 2.0	-18	
/arkers	Series L: 13.674 nH Series C: -34.572 nF	Quality factor: 0.014 S11 Phase: 170.86°	etter	-22	
Marker 1 3.81MHz  Marker 2 7.32MHz	Parallel X: 72.919 µH	S21 Gain: -09.049 GB S21 Phase: 10.61°	15	-24	
Marker 3 14.07MHz	Marker 3	1 122	13	-26	
Marker 4 18.12MHz	Impedance: 44.2+j640m Ω Series L: 7.2351 nH	Return loss: -24.169 dB Quality factor: 0.014		-28	
Enable Delta Marker     Reference     Hide data     Locked O	Series C: -17.685 nF Parallel R: 44.215 Ω Parallel X: 34.566 μH	S11 Phase:         173.31°           S21 Gain:         -68.328 dB           S21 Phase:         -18.58°	3.000M 16.50M	30.00М 3.000М 16.50	M 30.
DR	Marker 4	VSWD: 1168			
Estimated cable length: 0.157m	Impedance: 42.9+j1.03 Ω Series L: 9.0128 nH	Return loss: -22.194 dB Quality factor: 0.024	/ X X		
Time Domain Reflectometry	Series C: -8.5598 nF Parallel R: 42.884 Ω Parallel X: 15.733 μH	S11 Phase: 171.19° S21 Gain: -75.809 dB S21 Phase: -149.15°			
Set current as reference	4				
Reset reference	511		ILT		
Serial port control	Min VSWR: 1.082 @ 3.81000 Return loss: -28.059 dB	MHz	2.0		
Port COM4 (H) V Rescan	S21				
Disconnect Manage	Min gain: -85.847 dB @ 26.49	00MHz		-X	

### UnUn scan of Powder Core (T200-2) 9:1 UnUn with 440 Ohm Load

![](_page_26_Figure_1.jpeg)

### 20m 7-element Chebyshev low pass filter

#### S11 VSWR S11 Return Loss (dB) ~ Frequency: 5.00000 MHz VSWR: 1.064 Start 5MHz Center 17.5MHz 25 0 Impedance: 47.9-j2.2 Q Return loss: -30.175 dB 30MHz 25MHz Stop Span Series L: -70.171 nH Quality factor: 0.046 -5 Series C: 14.439 nF S11 Phase: -132.13° 4 62.03kHz/step Segments Parallel R: 48.015 Ω S21 Gain: -0.047 dB Parallel X: 30.501 pF S21 Phase: -101.68° 19.0 -10 Sweep settings ... 100% -15 Frequency: 14.1191 MHz VSWR: 1.196 Sweep Stop Impedance: 42.5+j3.47 Ω Return loss: -20.975 dB 13.0 -20 Series L: 39.097 nH Quality factor: 0.082 Markers Series C: -3.25 nF S11 Phase: 153.06° Parallel R: 42.773 Ω S21 Gain: -0.231 dB -25 Marker 1 5MHz Parallel X: 5.9066 µH S21 Phase: 23.96° Marker 2 14.119145MHz 🚺 🔘 7.0 -30 Marker 3 28.20109MHz Marker 3 Frequency: 28.2011 MHz VSWR: 278.506 -35 Marker 4 5MHz Impedance: 262m-j33.8 Q Return loss: -0.062 dB Series L: -190.76 nH Quality factor: 129.2 -40 5MHz 📘 🔿 Marker 5 1.0 5.000M Series C: 166.96 pF S11 Phase: -111.88° 17.50M 30.00M 5.000M 17.50M 30.00M Parallel R: 4.3681 kΩ S21 Gain: -66.940 dB Enable Delta Marker Reference Parallel X: 166.95 pF S21 Phase: -111.54° S11 Smith Chart S11 -S11 & S21 LogMag dB - 521 Locked O Hide data 0 TDR -10 Frequency: 5.00000 MHz VSWR: 1.064 Impedance: 47.9-j2.2 Ω Return loss: -30.175 dB Estimated cable length: 3.894m Series L: -70.171 nH Quality factor: 0.046 -20 S11 Phase: Time Domain Reflectometry ... Series C: 14.439 nF -132,13° Parallel R: 48.015 Ω S21 Gain: -0.047 dB -30 3 Parallel X: 30.501 pF S21 Phase: -101.68° Reference sweep -40 Set current as reference > ₽ < Reset reference -50 S11 Min VSWR: 1.059 @ 9.83873MHz -60 Serial port control Return loss: -30.806 dB ~ Rescan Port COM4 (H) -70 521 Manage Disconnect Min gain: -84.814 dB @ 29.0075MHz -80 Max gain: -0.047 dB @ 5.12407MHz Calibration ... Files ... -90 12:23 PM 💼 🧿 🚾 🛃 💷 🔮 101°F Sunny \land 🗓 📴 🜈 📣 喝 ĽЦ, 8/11/2023

NanoVNA Saver 0.6.2.post1.dev2+g2f8c534 (Sweep: nanovna\_2023-08-11 12:22:00 @ 404 points)

– 0 ×

### 10m-12m 5-element multiband Chebyshev low pass filter

![](_page_28_Figure_1.jpeg)

NanoVNA Saver 0.6.2.post1.dev2+g2f8c534 (Sweep: nanovna\_2023-08-11 13:15:38 @ 1010 points)

ð X

### 20m-17m 5-element multiband Chebyshev low pass filter

![](_page_29_Figure_1.jpeg)

### 40m 5-element multiband Chebyshev low pass filter

![](_page_30_Figure_1.jpeg)

### 80m 5-element multiband Chebyshev low pass filter

![](_page_31_Figure_1.jpeg)

INanoVNA Saver 0.6.2.post1.dev2+q2f8c534 (Sweep: nanovna\_2023-08-11 12:44:41 @ 1010 points)

![](_page_32_Figure_1.jpeg)

![](_page_33_Figure_1.jpeg)

![](_page_34_Figure_1.jpeg)

![](_page_35_Figure_1.jpeg)

![](_page_36_Figure_1.jpeg)

## NanoVNA Waveform showing the 14.3 MHz output waveform of the nanoVNA and a sample scan

![](_page_37_Picture_1.jpeg)

![](_page_37_Figure_2.jpeg)